DARPA-EPRI Megawatt Power Electronics

Program Review

Presented to:

DARPA/EPRI MEGAWATT
Power Electronics Review

The Hilton Alexandria Mark
Center

Alexandria, VA

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NORTHROP GRUMMAN

*S*ilicon *P*ower *CO*rporation

kTC
k Technology Corporation

THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

Thermal Management Analysis, Design and Fabrication Plan for SPCo 200 Amp Package

Analysis of SPCo 200 Amp Package

- Model Specifics
  - **Both Steady State and Transient Analysis**
  - **Two Types of Boundary Conditions**
    - **Forced Convection from Back Face**
    - **Perimeter (Liquid) Cooling Only**
  - Boundary Conditions
    - **No Radiation**
    - **No Convection other than Prescribed**
      - **h = 100 W/m²·K on Package Back Surface**

        h = 1000 W/m²·K on Two Edges
    - **12 GTO's Each Dissipating 50W**
    - **108 JFETS's Dissipating No Power**

Analysis of SPCo 200 Amp Package

- Model Specifics
  - Materials Used in Analysis
    - **Baseline Copper Tungsten (CuW 10:90)**
    - **CuW Encapsulated TPG with Thermal Vias**
  - Geometry
    - **GTO - 2mm X 2mm**
    - **JFET - 1mm X 1mm**
    - **Die Package 30mm X 30mm**
    - **Die Thickness = 0.6mm**
      - **Encapsulated TPG**
        - 0.1mm CuW foils on 0.5mm TPG

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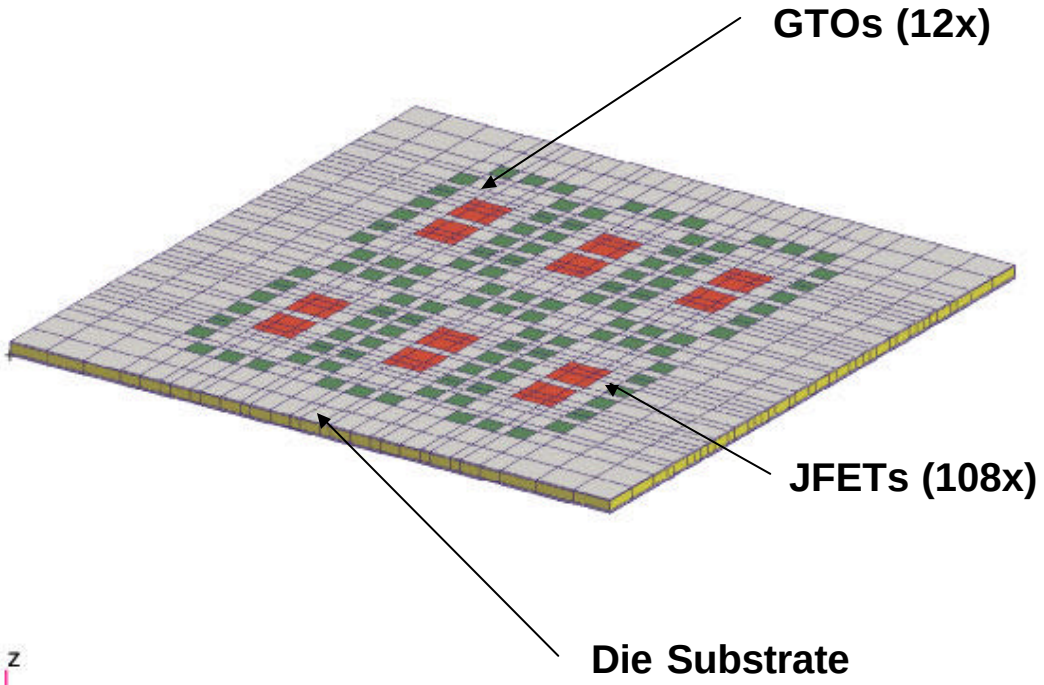
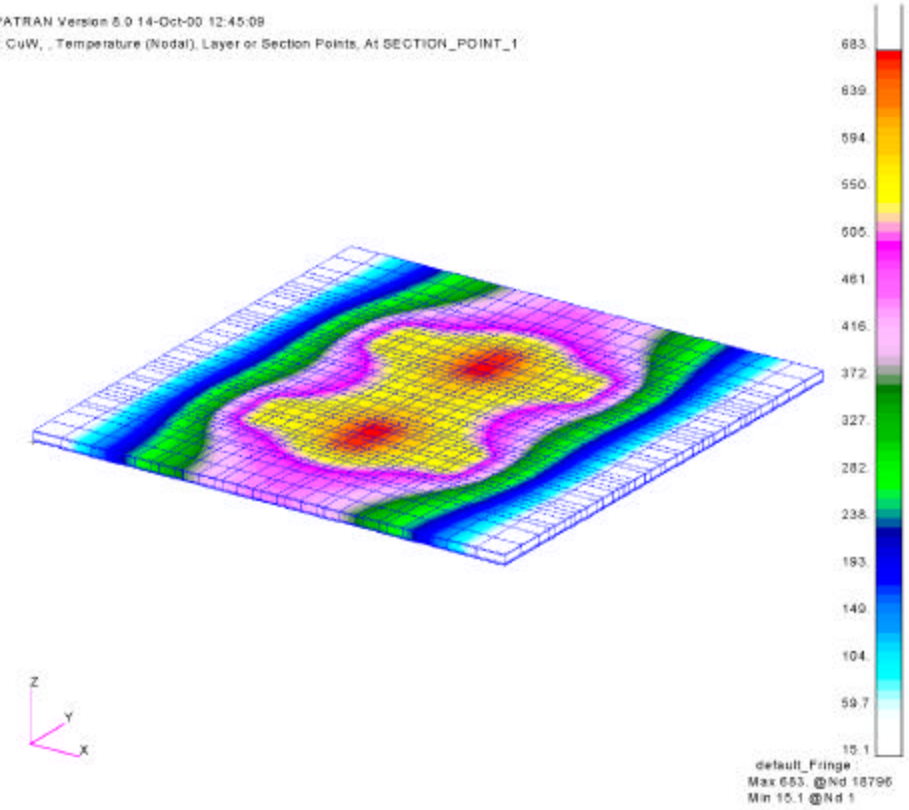
Analysis of SPCo 200 Amp Package

- Finite Element Model
  - **ABAQUS Finite Element Code**
  - **3D Heat Transfer Element**
  - **4800 Nodes**
  - **3393 Elements**
  - **Processed on HP C3000 Platform**



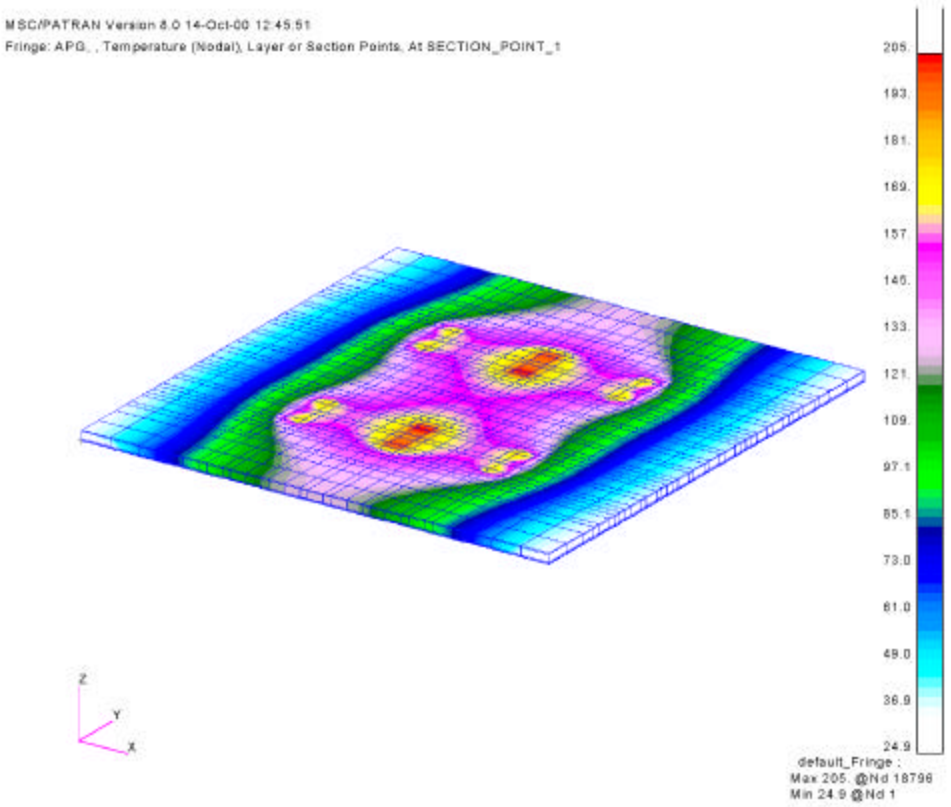
Steady State Results

- **Material - CuW**
- **Thickness - 0.6mm**
- **Maximum Temperature**
  - **683°C at GTO**



Steady State Results

- **Material - CuW Encapsulated APG w/Vias**
- **Thickness - 0.6mm**
- **Maximum Temperature**
  - **205°C at GTO**



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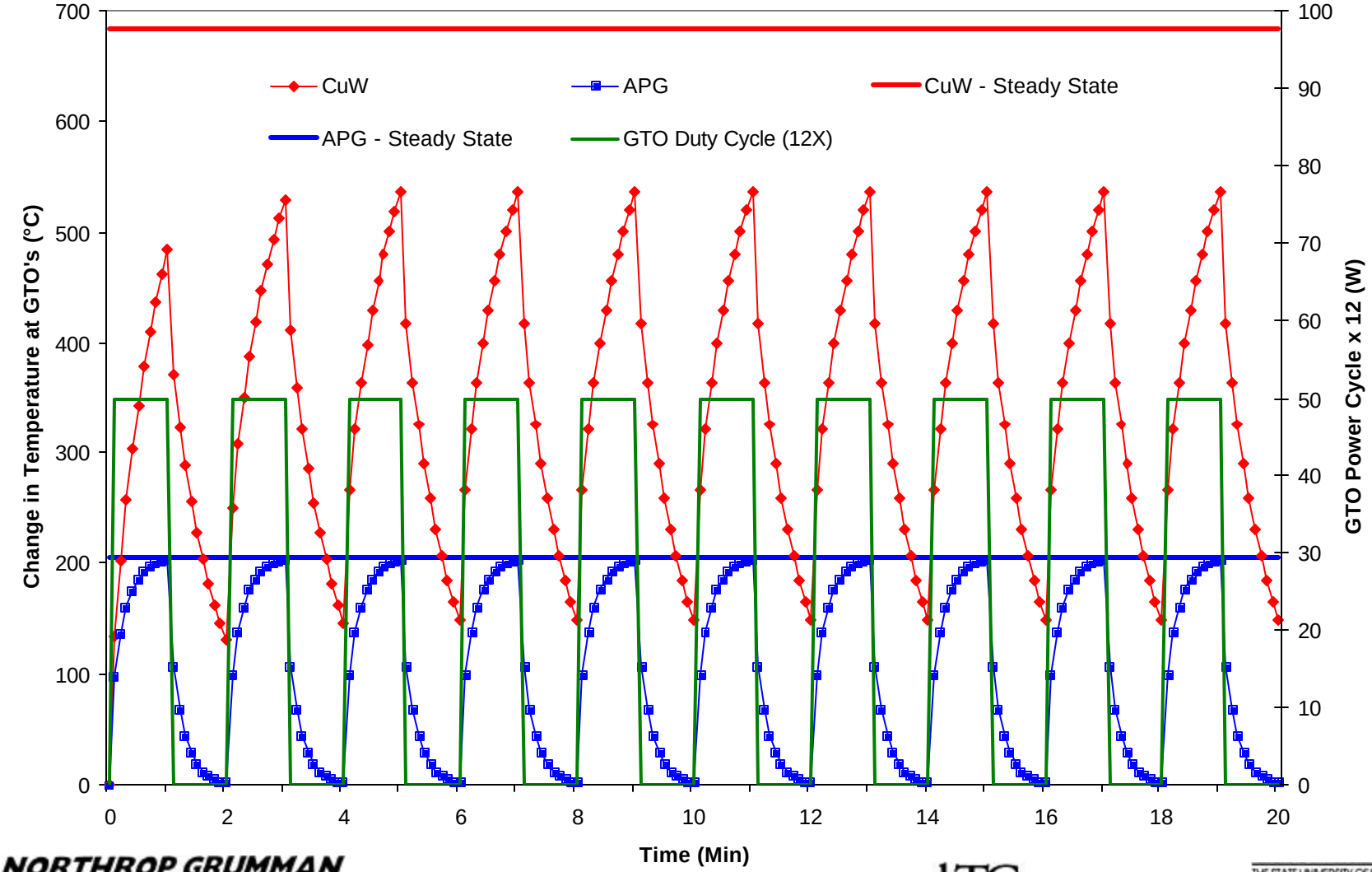
Transient Thermal Analysis Results

- **CuW**
  - **Results Show That the Diffusivity of CuW Cannot Efficiently Cool the SPCo Module**
    - **Thermal "Capacity" of CuW Limits Module Efficiency for Cooling**
    - **Thermal Conductivity Limitations Causes Undesired Gradients in the Package**
  - **CuW w/APG Insert**
    - **Analysis Shows >3X Decrease in Operating Temperature Over Solid CuW**
    - **Thermal Diffusivity of CuW/APG Module Will Reach Steady State (Most Efficient) and Will Also Shed All Latent Heat Before Next Cycle**
  - **Maximum Operating Temperatures Will Depend on "Real" Duty Cycle of SPCo Module**

SiC Megawatt Technology Development Program

Tranisent Thermal Response
CuW Baseline and CuW With APG Insert



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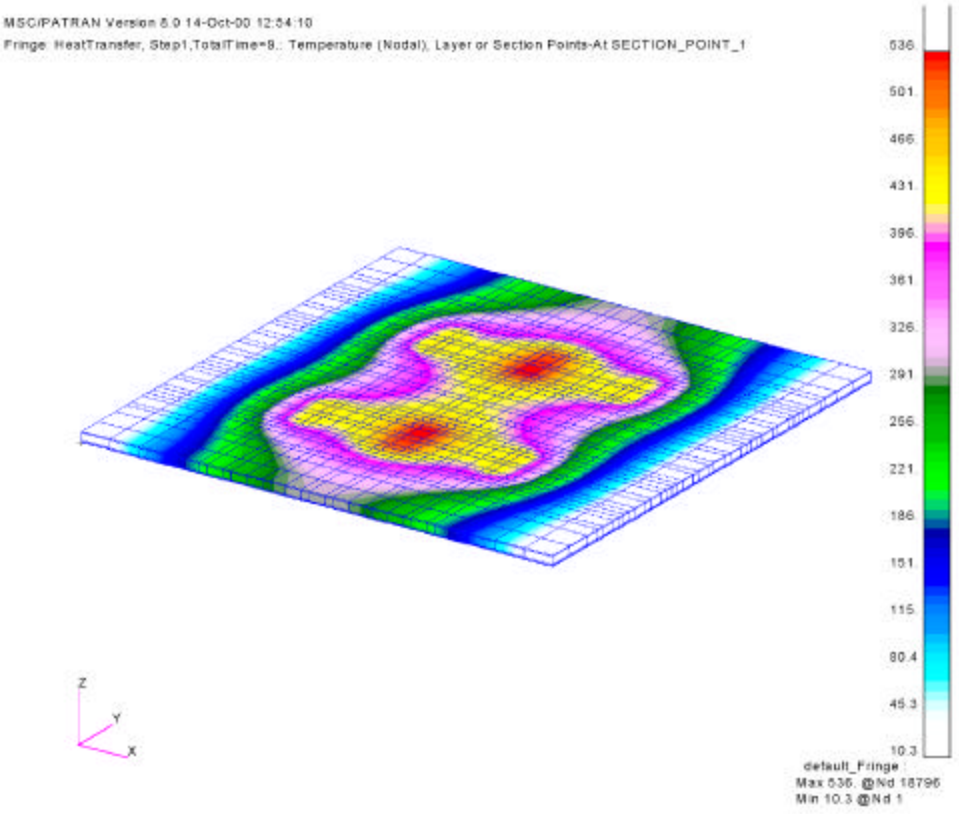
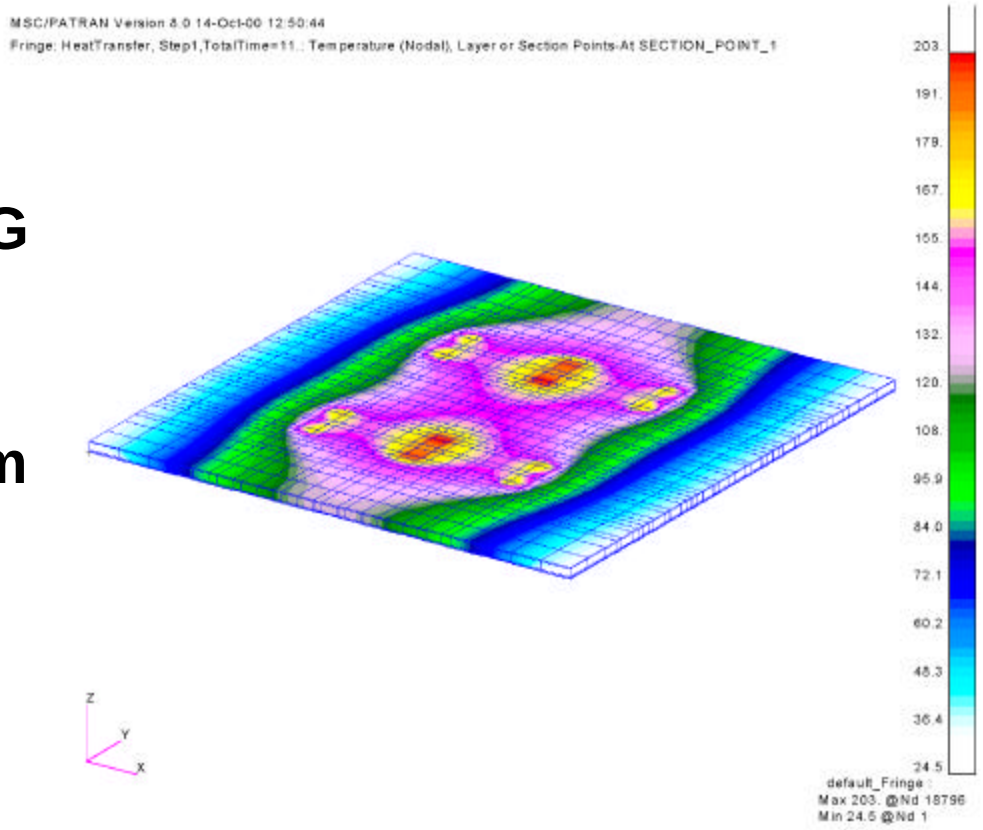
Transient Results

- **Material - CuW**
- **Thickness - 0.6mm**
- **Maximum Temperature**
  - **536°C at GTO**



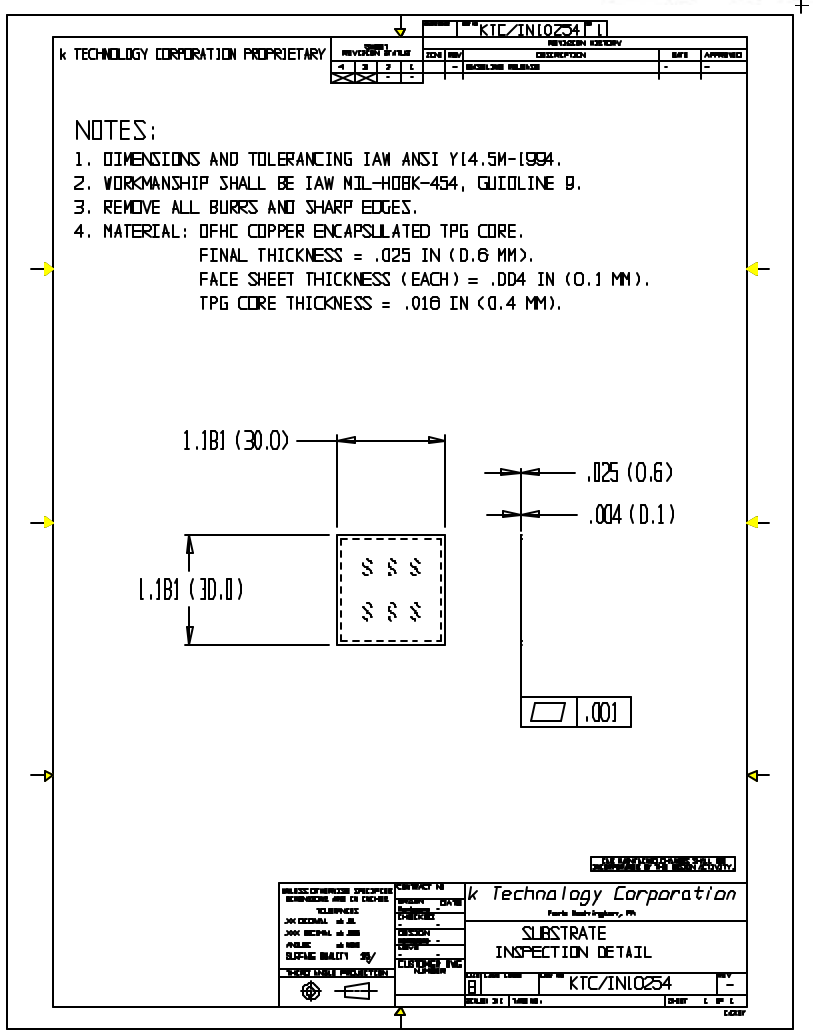
Transient Results

- **Material - CuW Encapsulated APG w/Vias**
- **Thickness - 0.6mm**
- **Maximum Temperature**
  - **203°C at GTO**



Design

- Annealed pyrolytic graphite encapsulated with OFHC copper
- Diffusion bonded assembly
- 68% APG volume fraction $k_x = k_y = 1168$ W/mK
- Copper vias place in high through thickness thermal flux regions (under the GTOs)



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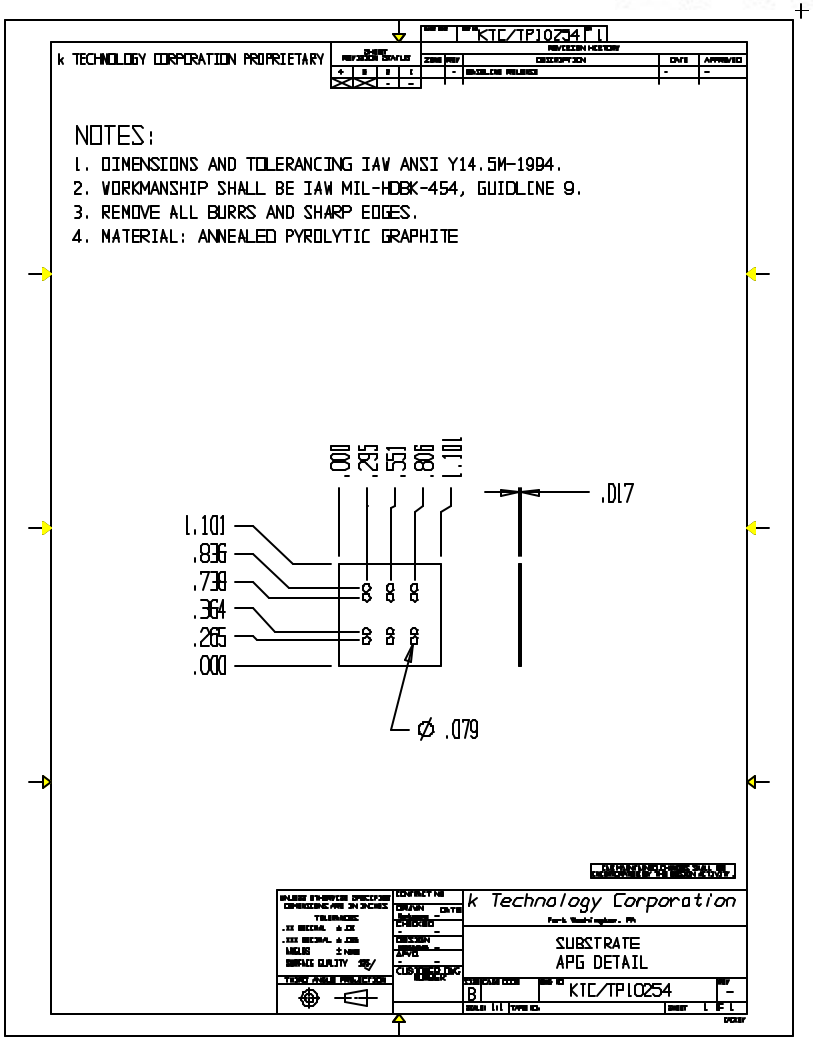
Design

- **Annealed pyrolytic graphite (APG) encapsulated insert**

  $k_x = k_y = 1700$ W/mK



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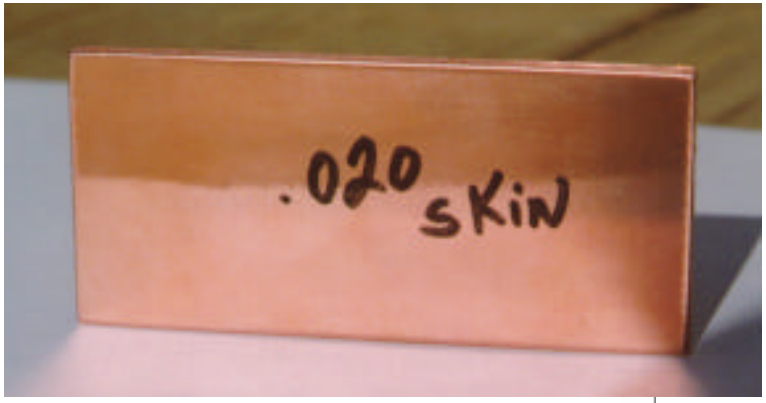
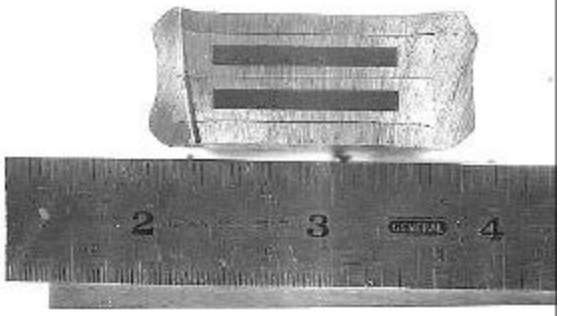
Fabrication

Establish the processing parameters of encapsulating APG within copper

Diffusion bonded copper encapsulated APG coupon

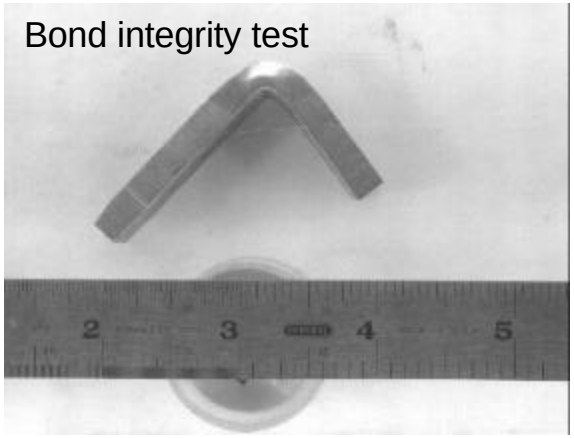




Section view of diffusion bonded coupons

- **Established time/temperature bake-out schedule**
- **Established pressure/ temperature/time diffusion bonding schedule**
- **Evaluated bond integrity**

Bond integrity test



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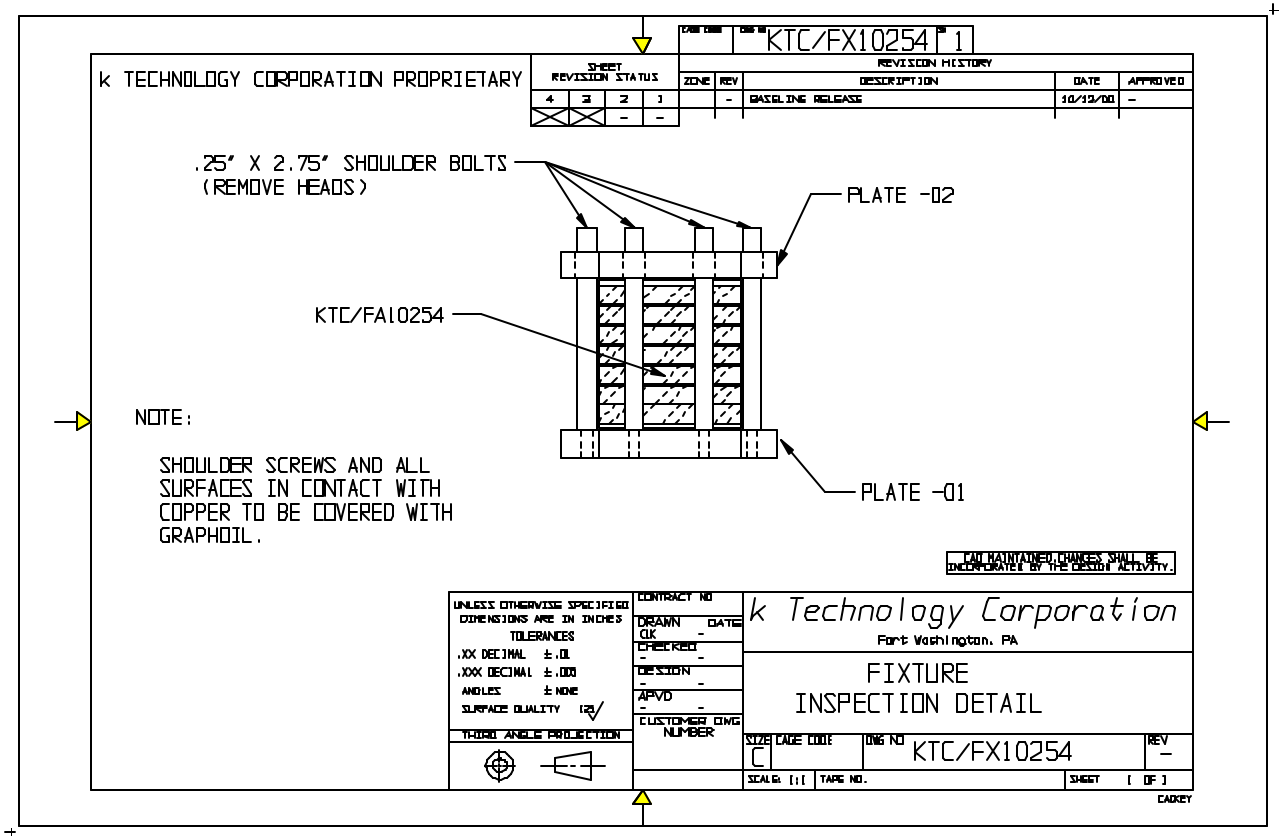
Fabrication

Bonding Fixture



Prototyping Tasks

- Final Review of Drawings and Release
- Prepare Pre-bond Assembly Kit (machined APG inserts, machined copper blanks and tooling)
- Assembly and Diffusion Bonding
- Final Machining
- Substrate Evaluation

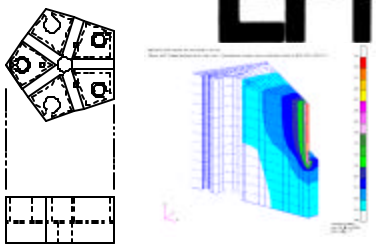
DARPA

EPRI

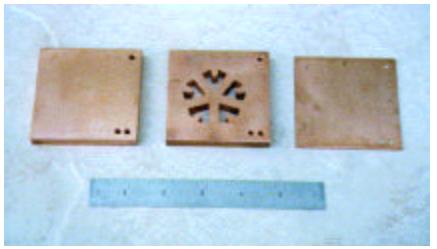
Spin-off Application

- Laser Diode Packaging
- .010” Copper Skin Thickness
- Three layer design
- Middle layer contains 5 TPG inserts oriented in x/y plane
- Assembly will hold 10 laser submounts

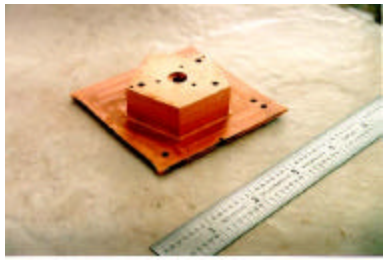
Design & Analysis



Pre-Bond Kit



Machining



Inspection

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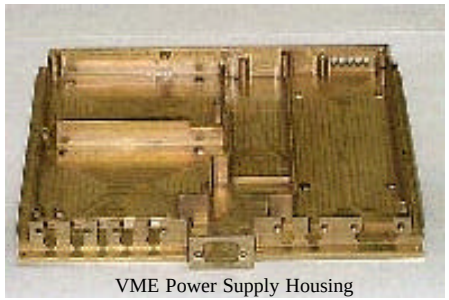
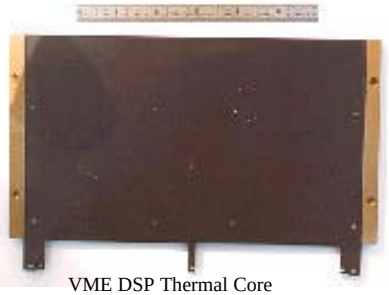
SiC Megawatt Technology Development Program

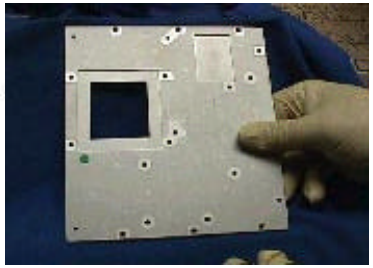
Encapsulated APG Products

Thermal Cores

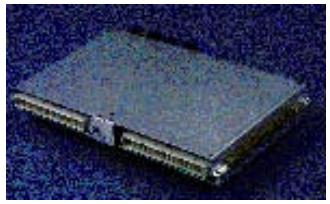

VME Power Supply Housing

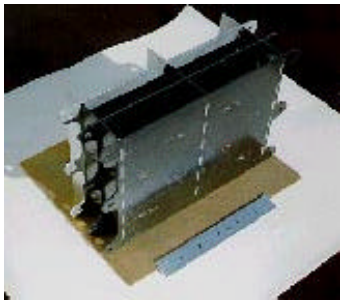

SEM-E DSP Thermal Core

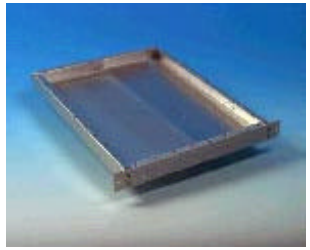

VME DSP Thermal Core


pace Station Power Supply Thermal Core

Chassis/Structures

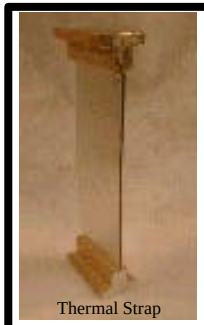

Ruggedized Commercial VME


Li-ion Battery Bracket


Conduction Cooled Chassis

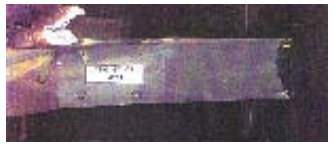

Radiator

Thermal Management Components


Thermal Strap

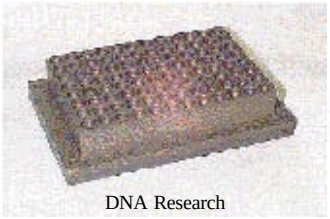

Flexible Thermal Foil

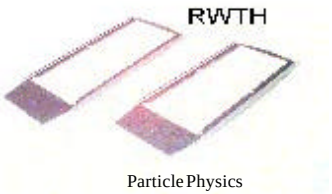

APG Platelet Polymer


Leading Edge

Heat Spreaders


RF Power-Amplifier Substrate


DNA Research



Particle Physics

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